Chapter Eight

Transatlantic Cooperation for a Competitive and Sustainable Biofuel Industry

Tamás Kenessey

Humanity has never before faced so much uncertainty about the sustained availability of resources and energy indispensable for its future development. The *International Energy Agency's World Energy Outlook 2010* projects that world primary energy demand will increase by 36 percent until 2035, even if nations implement recently adopted policy measures on resource efficiency. Fossil fuel use is restricted by many factors, such as the increasing costs of extraction, the situation of reserves in politically unstable parts of the world, the need to reduce anthropogenic greenhouse gas (GHG) emissions and the energy importing nations' pursuit of greater energy security. In order to limit the global temperature rise to below 2°C governments have to take bold actions without delay. GHG emissions should be cut by at least one-third compared with business-as-usual models until 2050. Renewable energy will play a central role in the future energy mix. In the short term, renewables are required to meet the world's increasing demand in a sustainable and economically competitive way. In the medium- and long term, their role is to gradually replace fossil fuels. According to the special report of the United Nations Intergovernmental Panel on Climate Change (UN IPCC), with the right backing from policymakers they could provide up to 80 percent of the world's primary energy supply by 2050.[1]

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[1] O. Edenhofer, R. Pichs, Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow, ed. "IPCC, Summary for Policymaker," in *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation* (Cambridge, United Kingdom: Cambridge University Press, 2011). Available at: http://srren.ipcc-wg3.de/report.

Definition of Biofuels

Biofuels are liquid or gaseous fuels produced from organic matter derived from plants, animals and waste and primarily used in the transport sector. They can be classified according to feedstock, technological pathways, historical development or the maturity and commercialization of the technology. *First generation* biofuels are based on traditional feedstock such as sugarcane, corn, soybeans and palm oil. These technologies have already reached technological maturity and production is done on commercial scale. *Second generation* biofuels use agricultural and forestry residues and left-overs and usually apply cellulosic conversion technologies. *Third generation* biofuels are produced from a wide range of feedstock specially designed for energy purposes and apply advanced conversion technologies that are currently under development. Another classification divides biofuels to *conventional technologies* that use well-established processes on industrial scale and *advanced technologies* that are still in the R&D or demonstration stage and need further improvement before commercialization.

Biofuels in the Global Energy Mix

Biofuels will play a central role in gradually replacing fossil fuels in the transport sector. The International Energy Agency (IEA) estimates that the transport sector accounts for half of the global primary oil consumption. Transport is almost entirely based on petroleum which supplies 95 percent of its total energy use. At the same time, according to conservative assessments, transport was responsible for approximately 23 percent of all anthropogenic GHG emissions in 2004 and since then this share has increased.[2] The IEA has estimated that transport related emissions could double between 2000 and 2050 and the bulk of these will occur in non-OECD countries.[3] Biofuels currently

[2] B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer , ed., "Transport and its infrastructure," in *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2007). Available at: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter5.pdf.

[3] *World Energy Outlook 2010* (Paris, France: OECD / International Energy Agency, 2011).

provide around three percent of total transport fuel and their share is quickly increasing. According to the *IEA's Technology Roadmap Biofuels for Transport* the share of biofuels can grow to 27 percent of total transport fuel by 2050, saving 2.1 gigatonnes of CO_2 emissions yearly.[4] To meet this ambitious target, a number of challenges have to be overcome. Economic and sustainable production of feedstock, effective conversion pathways and the compatibility of the final product with current distribution and end-of-use infrastructure are the main development bottlenecks. A number of serious *social and ethical issues* also have to be addressed. Evidence showed that conventional biofuels made from foodstuffs contributed to soaring food prices in 2007. Due to the indirect land use change effect of feedstock production, their greenhouse gas balance proved to be worse than previously expected. But for all their present flaws biofuels have a huge potential. They can reduce our dependency on oil and consequently improve energy security. Advanced technological pathways using waste, agricultural and forestry residues or plants specially designed for energy use offer substantial GHG reductions and avoid the food versus fuel conundrum. Partly owing to recent events in the energy industry, partly to economic considerations and partly to developments in the biofuel industry, the ground is shifting back towards biofuels.

The Biofuel Industry Today

The global biofuel production in 2010 exceeded 100 billion liters and provided nearly three percent of global transport fuel supply. The production increased more than fivefold in the last ten years. Continued policy support, high oil prices in recent years, the need to reduce GHG emissions in the transport sector and technological innovations all contributed to the rapid expansion. Forecasts say that demand will continue to rise in the foreseeable future and biofuels can provide one-tenth in 2030 and up to 27 percent in 2050 of all transport fuels.[5] Cur-

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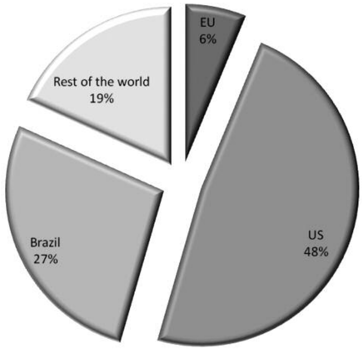
[4] *Technology Roadmap*, *Biofuels for Transport* (Paris, France: OECD / International Energy Agency, 2011).

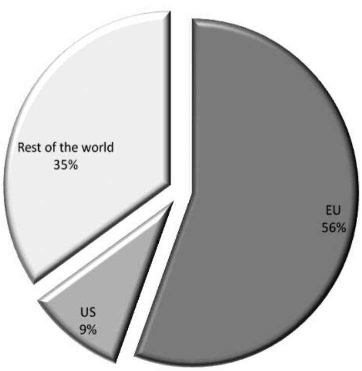
[5] The calculations derive from the *BP Statistical Review of World Energy* and the IEA's Technology Roadmap, Biofuels for Transport. *BP Statistical Review of World Energy*, (London, United Kingdom: BP p.l.c., 2010) and *Technology Roadmap*, *Biofuels for Transport* (Paris, France: OECD / International Energy Agency, 2011).

Figure 1. Share of U.S., Brazil, EU and rest of the world in bioethanol (2009)



Source: World Energy Outlook (2010) and Technology Roadmap: Biofuels for Transport (2011), OECD / International Energy Agency

Figure 2. Share of EU, U.S. and rest of the world in biodiesel (2009)



Source: World Energy Outlook (2010) and Technology Roadmap: Biofuels for Transport (2011), OECD / International Energy Agency.

rently the United States, Brazil and the European Union dominate the market. They all apply a mix of policy measures including R&D and investment support, blending mandates, tax incentives and certification schemes to stimulate the growth and development of the industry.

Brazil

In many respects, the South American nation can provide an example for other countries on how to build a market-based and sustainable biofuels industry. Brazil has been in the forefront of ethanol production since the 1970s. As a result of continuous state support, long-term targets and a relatively stable regulatory environment, companies made significant investments in the sugarcane ethanol sector. Since the 1990s the government gradually reduced ethanol subsidies and abolished production quotas. Today the price of sugar and ethanol is regulated by the market and this led to substantial efficiency gains. Brazil currently applies a 20-25 percent blending mandate for bioethanol and a five percent blending mandate for biodiesel as per 2013. Sugarcane-based ethanol provided 21 percent of Brazil's road transport fuel demand in 2008. Brazilian sugarcane ethanol is a conventional technology, but its price is competitive with petrol and it offers up to 86 percent GHG reduction compared to petrol.[6]

United States

Corn-based biofuel production started in the United States following the 1973 oil crisis. With almost 50 billion liters in 2010, the United States is currently the world's leading producer of bio-ethanol and has an ambitious target to produce 136 billion liters by 2022. 60 billion liters of this should derive from advanced, lingo-cellulosic feedstock. Biodiesel production is not significant compared to ethanol.[7] Corn-based ethanol production is relatively cheap, but serious concerns had been raised about its sustainability. Almost 40 percent of all U.S. corn is

[6] Searchinger et al. (2008) in Perrihan Al-Riffai, Betina Dimaranan, David Laborde, *Global Trade and Environmental Impact Study of the EU Biofuels Mandate* (Brussels, Belgium: International Food Policy Institute / European Commission, 2010).

[7] Production of 2 billion liters in 2009. Data source: National Biodiesel Board http://www.biodiesel.org/.

expected to go to biofuel production in 2011,[8] and among all biofuels U.S. corn-based bioethanol is believed to have had the greatest effect on soaring food prices in 2007. Moreover, corn production requires fossil fuels, a great quantity of fertilizers, and water. The U.S. applies a complex system of support schemes. On the federal level this includes tax reductions, direct subsidies for ethanol and biodiesel, and a tariff system designed to limit imports especially from Brazil. States are also allowed to adopt tax exemptions, subsidies and blending mandates different from federal ones.[9] In June 2011 a cross-party movement in the U.S. Senate voted to end the corn-based ethanol tax credits and the 54 cent per gallon tariff on ethanol imports. The bill, however, extended tax credits for the cellulosic ethanol industry until 2015.[10] Capital investments also receive subsidy from the government. President Barack Obama unfolded the administration's new energy security plan in March 2011.[11] The president announced to spend up to 510 million USD to build four new bio refineries with a combined capacity of more than 80 million gallons (approximately 300 million liters), and offered a special partnership for the private sector with the U.S. Department of Energy, Department of Agriculture, the U.S. Navy and U.S. Air Force. Government support is needed as technical difficulties slowed down the development and commercialization of advanced biofuels. Due to the higher than expected production costs, the U.S. Department of Agriculture had to scale down its estimated capacity of advanced biofuels to only 40 million liters, one-tenth of the originally expected amount for 2010.

[8] *Feed Grains Data, August 2011*, United States Department of Agriculture, Economic Research Service. Available at: http://www.ers.usda.gov/Data/FeedGrains/FeedYearbook.aspx#FSI.

[9] Perrihan Al-Riffai, Betina Dimaranan, David Laborde, *Global Trade and Environmental Impact Study of the EU Biofuels Mandate* (Brussels, Belgium: International Food Policy Institute / European Commission, 2010).

[10] "Senate deal would axe $6 billion ethanol tax credit," *Reuters*, July 7, 2011. Available at: http://www.reuters.com/article/2011/07/07/us-usa-ethanol-deal-idUSTRE7663OS20110707.

[11] *Remarks by the President on America's Energy Security*, March 30, 2011. Available at: http://www.whitehouse.gov/the-press-office/2011/03/30/remarks-president-americas-energy-security.

The European Union

Biofuels provide approximately four percent of all transport fuels in the EU27. The EU's biofuel industry is dominated by biodiesel production, owing to the fact that diesel engines account for roughly half of the European car market. In 2009 European biodiesel production exceeded 10 billion liters, around 56 percent of world production.[12] It is entirely based on first generation feedstock, such as rapeseed, sunflower and soybean. Bioethanol production from corn and wheat was 3.7 billion liters in 2009.[13] The European Union has a target of 10 percent renewable energy in transport by 2020, for which lignocellulosic biofuels and biofuels made from waste and residues count twice. To help achieving this target the EU authorized member states in an Energy Tax Directive to introduce tax reductions for biofuels. The EU's Common Agricultural Policy since 2003 supports the production of energy crops in the form of decoupled direct payments and targeted support. The EU seemed to be on track to meet its 10 percent target, but the recent debate on the indirect land use change (iLUC) effect of European biofuel policies and the lack of commercially viable advanced technologies slowed down the progress. Another restrictive factor is that the biomass producing capacity of Europe is already exploited to 40-75 percent.[14] Compared to other parts of the world, the EU is short of unused arable land and the future growth of European biofuel industry will need feedstock import. As a consequence the EU will be interested in gradually dismantling the trade barriers that currently limit the free flow of feedstock and biofuels on world markets.

[12]Source of data: Biofuels platform—http://www.biofuels-platform.ch/en/infos/eu-biodiesel.php

[13]Ibid.

[14]M. Altmann, P. Schmidt, W. Weindorf, Z. Matra, A. Brenninkmeijer, J.-C. Lanoix, O. van den Kerckhove, C. Egenhofer, A. Behrens, J. Nuñez Ferrer, R. Bleischwitz, A. Crisan, *The assessment of potential and promotion of new generation of renewable technologies* (Brussels, Belgium, study commissioned by the European Parliament, 2011). Available at: http://www.lbst.de/ressources/docs2010/EP-02_Renewables_JUNE 2010_PE-440-278.pdf.

Conventional Biofuels and Their Shortcomings

Sugar and starch-based conventional bioethanol currently provides more than three-quarters of all biofuel production. It has been a hundred years since Henry Ford designed the famous T-model to run on this fuel. The basis of the process is the fermentation of sucrose or glucose to bioethanol. Corn, sugarcane, sugar beet, sweet sorghum and wheat are the most frequently applied feedstock. Conventional biodiesel can be produced from vegetable oils, animal fats and used cooking oil by a chemical process called transesterification. Mostly sunflower, rapeseed, soybean and palm oil are used as feedstock. Biogas is the result of the anaerobic digestion of organic waste, animal manure, sewage sludge and plant residues. It can be directly burnt to heat and produce electricity. Cleaned from contaminations and upgraded to biomethane it also can be injected into natural gas grids or used in natural gas vehicles. The share of biogas in transport fuels is currently negligible. The production costs of conventional biofuels are already comparable to that of fossil fuels. The IEA estimates that corn and cane bioethanol is produced for 62-75 U.S. cents per liter gasoline equivalent,[15] depending on yield, geographical and weather conditions. At the same time, in 2010 average prices, a liter of petrol is produced for about 54 cents.[16]

Food vs. Fuel

Although they have become increasingly competitive in recent years, conventional bioethanol and biodiesel have a number of shortcomings. They are produced from the edible part of plants and their production relies heavily on fossil fuels. Consequently they contributed in recent years to the increase in food prices and had little effect to cut greenhouse gas emissions. Measuring the impact of biofuels on food prices is a complex task. They played an undeniable role in the 2007-2008 food price crisis together with other factors, such as

[15]Liter gasoline equivalent is the amount of alternative fuel it takes to equal the energy content of one liter of gasoline (energy content 33.5 MJ/liter).

[16]Costs are calculated based on global average retail price without taxation. Source of data: *Technology Roadmap, Biofuels for Transport*, (Paris, France: OECD / International Energy Agency, 2011).

the increased demand for meat products in emerging economies, adverse or extreme weather conditions in major producer countries, low level of global stocks, protective policies on the export or import of foodstuffs in certain countries and, last but not least, increased oil prices. Sophisticated global equilibrium models came to the conclusion that "although individual crop prices appear to be affected by biofuels, the impact of biofuels on global or aggregated food prices is rather small."[17] An extensive 24 month-long study found that only 12 percent of the rise in the IMF's food price index could be attributed to biofuels.[18] Approaching the problem from the other end, however, shows that rising crop prices seriously affect the competitiveness of conventional biofuels. The price of the final product *depends heavily on feedstock prices*, which represent 45 to 70 percent of production costs.[19] The price of sugarcane, corn and wheat became ever more volatile in recent years. The mounting demand for food, fiber and energy crops of the world's growing population will result in even higher agricultural prices. Future feedstock production is also dependent on available arable land, and additional intensive inputs like water and fertilizers. The U.S. Department of Agriculture predicts that if the United States 2030 biofuel target is met using only corn-derived ethanol, agricultural water use could increase six-fold.[20] Land, water and fertilizer demand and the consequent competition with food production are the most serious economic constrains of conventional biofuel technologies.

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[17] Govinda R. Timislina & Ashish Shreshta, Environment and Energy, Development Research Group, *Biofuels: Markets, Targets and Impacts*, (Washington DC, United States: The World Bank, 2010).

[18] Baier, Scott, Mark Clements, Charles Griffiths, and Jane Ihrig, "Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet," in *International Finance Discussion Papers*: Number 967 (Washington DC, United States: Board of Governors of the Federal Reserve System, 2009).

[19] *Transport, Energy and CO_2* (Paris, France: OECD / International Energy Agency, 2011).

[20] K.C. Stone, P.G. Hunt, K.B. Cantrell, K.S. Ro, *The potential impacts of biomass feedstock production on water resource availability* (Washington DC, United States: United States Department of Agriculture, Agricultural Research Service, 2009). Available at: http://ddr.nal.usda.gov/bitstream/10113/38481/1/IND44306549.pdf.

Table 1. Greenhouse Gas Balances of Biofuels in 2005

GHG Emissions (% change)

	Feedstock	Previous Land Use	No LUC	With Direct LUC	With indirect LUC
Biodiesel	Waste oil	n.a	-90	n.a	n.a
	Rapeseed	Cropland	-58	-58	+5 to + 69
	Rapeseed	Pasture	-58	-25	+39 to + 102
Ethanol	Sugar cane (Brazil)	Cropland	-71	-71	-35 to +1
	Maize	Cropland	-55	-55	-22 to + 11
	Maize	Pasture	-55	-37	-5 to + 28
	Wheat	Cropland	-49	-49	+6 to + 63
	Wheat	Pasture	-49	-22	+ 36 to + 92

Source: Fritsche & Wiegmann (2008) in Fischer et al. (2009)

Note: Waste oil includes waste vegetable and animal oils. LUC stands for land use change. Direct LUC refers to emissions including those arising from the land conversion to cultivate the biofuel, whereas indirect LUC refers to emissions including those arising from the conversion of land elsewhere to replace production displaced by biofuel cultivation.

Greenhouse Gas Savings

The greenhouse gas balance of conventional biofuels also failed to meet expectations. *Fritsche & Wiegmann (2008)* estimated that most of the conventional feedstock and conversion technologies result in additional GHG emissions compared to fossil fuels if direct and indirect land use change is included.[21]

Four studies leaked from the services of the European Commission in July 2011 to the Reuters news agency came to similar conclusions. They suggest that the EU's renewable energy target in the transport sector may lead to additional emissions instead of avoiding greenhouse gases. The European Commission's internal calculations state that compared to the CO_2 emissions of 83.8 grams per megajoule for fossil fuel, palm oil causes 105 grams, soybean 103 grams, rapeseed 95 grams, sunflower 86 grams, wheat 47 to 64 grams, corn 43 grams of CO_2. Only sugar beet's 34 grams, sugarcane's 36 grams

[21]Fritsche & Wiegmann (2008) in Fischer, Günther, Eva Hizsnyik, Sylvia Prieler, Mahendra Shah and Harrij van Velthuizen, *Biofuels and Food Security* (Vienna, Austria, prepared by the International Institute for Applied Systems Analysis for OPEC Fund for International Development, 2009).

and cellulosic ethanol's 9 grams of CO_2 emissions result in substantial GHG savings.[22]

Energy Density

A further weakness is that the energy density of bioethanol is only about 65 percent of that of gasoline, while biodiesel's energy performance is around 90 percent of diesel fuel's.[23] Thus, the blending of conventional biofuels is limited to 10-15 percent in the case of ethanol and around 20 percent for biodiesel. Above this so-called "*blending-wall*" only flex-fuel cars with modified engines can run on higher biofuel blends.

Future Prospects for Biofuels

For all their present day weaknesses, biofuels are considered to be an integral part of the future energy mix in the transport sector. Biofuels can reduce our dependency on oil, improve energy security and cut back greenhouse gas emissions. They are energy rich, liquid, easy to transport and almost entirely compatible with the current distribution and end-of-use infrastructure. Until the proliferation of plug-in hybrid electric vehicles (PHEVs), which require the dramatic development of battery technology and the considerable improvement of the current electric network, there is no real alternative to biofuels in the transport sector. Even with PHEVs on the market, diesel and kerosene replacements are expected to gain further ground in the heavy transport modes and air transport that have limited low-carbon fuel alternatives. The IEA predicts that by 2050 biofuel demand will reach 32 exojoules (EJ), up from today's 2,5 EJ, resulting in more than 100 million hectares in land demand.[24] Biofuel's share in total transport fuels will increase from approximately three percent to around 27 percent.

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[22] "Factbox: What EU studies say on biofuels' indirect damage," *Reuters*, Brussels, Jul 8, 2011. Available at: http://uk.reuters.com/article/2011/07/08/us-eu-biofuel-factbox-idUKTRE7672XF20110708.

[23] *Bioenergy Conversion Factors* (Oak Ridge, United States: Oak Ridge National Laboratory, 2008).

[24] *BLUE Map Scenario—Energy Technology Perspectives, Scenarios & Strategies to 2050*, (Paris, France OECD / International Energy Agency, 2010).

Biomass is a plentiful resource of energy. The maximum global technical biomass potential from sources that can be sustainably exploited is estimated at 475 EJ by 2050.[25] This is almost triple of the bioenergy (including biofuels) demand projected in the *BLUE Map Scenario of the IEA by 2050.*[26] To harness that amount of energy, however, substantial investments and infrastructural developments have to be made, and the IEA estimates that an additional 70 million hectares of land will be necessary to meet this target.

Conventional technologies will continue to improve in efficiency and will be increasingly competitive with petrol. Their environmental performance will also get better. The IEA predicts that the majority of growth until 2020 will be met by conventional biofuels. Subsequently, however, advanced biofuels are expected to reach technological maturity and have to be deployed on a commercial scale. New technological pathways have to be developed that can use a broad range of feedstock and transform biomass into fuel in a cost effective and environmentally sustainable way. There is no one-size-fits-all solution; at least a dozen of promising technological pathways compete for commercialization. The future of the biofuel industry lies in the diversity of feedstock, conversion technologies and final products. This diversity makes biofuels capable of adjusting to the needs of different geographic regions and transport sectors.

Advanced Technological Pathways

Petrol sets a high standard for the biofuel industry. Ideal biofuels should have similar characteristics as the fossil fuel they are intended to substitute. They have to store as much energy as gasoline or diesel. They have to be compatible with current processing chains in existing refineries, with distribution networks or directly with the vehicles that

[25]Dornburg, V., Faaij, A., Langeveld, H., van de Ven, G., Wester, F., van Keulen, H., van Diepen, K., Ros, J., van Vuuren, D., van den Born, G.J., van Oorschot, M., Smout, F., Aiking, H., Londo, M., Mozaffarian, H., Smekens, K., Meeusen, M., Banse, M., Lysen E. andS. van Egmond (2008), *Biomass Assessment: Assessment of global biomass potentials and their links to food, water, biodiversity, energy demand and economy*, MNP, Bilthoven.

[26]*Energy Technology Perspectives, Scenarios & Strategies to 2050*, (Paris, France: OECD / International Energy Agency, 2010).

use them. They should go beyond the food versus fuel debate by using a broad range of non-edible biomass that can be grown on marginal land with relatively little amount of agricultural inputs. Finally, they should provide considerable GHG reductions compared to fossil fuels. The next part presents the most promising technological pathways and the technological challenges they have to overcome in order to reach technological maturity and commercial scale.

Lignocellulosic Bioethanol

Bioethanol can be produced by breaking down the entire lignocellulosic structure of the plant instead of just using its sugar or starch rich parts.[27] The process requires pretreatment using heat and strong chemicals, then enzymes or microbes to liberate sugars. Sugars are then fermented and distilled to produce ethanol. The technological challenge is to find the ideal biochemical process that breaks down the complex polymers to simple sugars in a cost effective way. Different processes use a broad range of feedstock from agricultural and forestry residues like corn stalks and wood chips to energy crops. The ideal energy crop is fast growing, perennial, can be cultivated on marginal land and has little water requirements. *Willow* and *poplar trees*, perennial grasses such as *miscanthus* and *switchgrass* are considered to be the best candidates for the future feedstock of advanced cellulosic bioethanol. Cellulosic ethanol has better GHG balance and performs better in terms of land use requirements than conventional technologies. The IEA calculates that the average cost of a liter of petrol equivalent to cellulose-based ethanol is around 1.1 U.S. dollar. Although this production cost is almost double of conventional bioethanol's, demonstration plants producing cellulosic ethanol are already running on both sides of the Atlantic. *Commercial deployment* has also started in 2011.

Next Generation Biodiesels

Heavy-duty vehicles and aviation have an especially big stake in high-energy content replacements of diesel and kerosene-type fuels. As the IEA put it, "Advanced biodiesel and bio-kerosene will become

[27] Plant cell walls of woody biomass contain three types of carbon-based polymers: cellulose, hemicelluloses and lignin.

increasingly important (...) since demand for low-carbon fuels with high energy density is expected to increase significantly in the long term."[28] Advanced biodiesel can be produced either by *hydrogenating vegetable oils*,[29] or with a two step process in which biomass is first gasified and then converted with the *Fischer-Tropsch synthesis* to a high energy density synthetic liquid (bio-oil). Advanced biodiesel is currently in the *pilot and demonstration stage* and could become fully commercialized in the near future.

Bio-Synthetic Gas

Biomethane (syngas) can be produced via the gasification or pyrolysis of biomass.[30] After purification, the *syngas* can be injected in natural gas networks, in natural gas vehicles, or can be converted to liquid fuel using the Fischer-Tropsch synthesis. The advantage of this technology is that it can use a broad range of feedstock.

Algae-Derived Biodiesel

For a long time the most anticipated technological pathway has been the algae-based biofuel production. Algae can yield up to one hundred times more oil per hectare than conventional sources like soybean or sunflower. Production can take place in artificial open ponds or in so-called closed bio-reactors on non-arable land. Certain algae-strains are able to use brackish, salt or wastewater, hence reducing the fresh water use. They reproduce quickly and yield high energy density oils and by-products rich in carbohydrates. Algae-based biofuel production, however, is still in the *R&D and demonstration stage*. The estimated cost of the raw oil from algae ranges from 0.75 to 5 U.S. dollars per liter.[31] In its 2009 report Accenture states that "algae will be the most difficult and will take the longest to achieve commer-

[28] *Technology Roadmap*, *Biofuels for Transport* (Paris, France: OECD / International Energy Agency, 2011).

[29] Hydrotreated vegetable oil (HVO).

[30] Gasification is process that converts biomass to a mixture of gaseous materials (syngas) at high temperatures, with a controlled amount of oxygen. Pyrolysis occurs under high pressure and high temperature in absence of oxygen.

[31] *Technology Roadmap*, *Biofuels for Transport*, (Paris, France: OECD / International Energy Agency, 2011).

Table 2. Oil yields for algae and other biodiesel feedstock

Feedstocks	Oil yield (barrels/ha/year)
Soybean	2.5
Sunflower	5
Jatropha	12
Palm oil	36
Algae	360

Source: Claude Mandil and Adnan Shihab-Eldin, Assessment of Biofuels Potential and Limitations, a report commissioned by the International Energy Forum, February 2010.*
*Another calculation came to the conclusion that algae can yield 1200 gallons (approximately 4540 liters) of oil per acre compared to a yield of 48 gallons (approximately 181.5 liters) from soybean. Source: Darzins, Al, Sustainable Algal Biofuels at Scale: A Prospectus (Albuquerque, New Mexico, U.S., 2009), paper presented at the annual Southwestern Biofuels Policy Summit, May 27-28, 2009.

cial scale."[32] Algae are considered essential for the production of high energy density biodiesel, airline drop-ins and jet fuel on scale. For their promising high productivity and their energy performance several big oil companies made considerable investments in algal biofuel research and pilot plants.

Other Biofuel Technologies

To overcome the problem that ethanol's low energy density presents, scientists also research biochemical processes that result in longer hydrocarbon chains. *Butanol* packs almost as much energy as gasoline and can be blended with fuel in higher proportions. The technological challenge here is to genetically manipulate yeast strains to produce butanol instead of ethanol from sugars. The first butanol-producing commercial plants are expected to open in 2012-2013.[33] *Dimethylether* (DME) is a promising fuel in diesel engines and can be produced from syngas. But the technology is still in its demonstration stage. *Pyrolysis oil*, or bio-crude, can be produced by rapidly heating the biomass to high temperatures and then cooling it down. Bio-crude

[32] M. Stark et al., *Betting on Science: Disruptive Technologies in Transport Fuels*, (Accenture, 2009).

[33] Neil Savage, "The Ideal Biofuel," *Nature* Vol. 474, S9–S11, 23 June 2011.

Table 3. Commercialization status of main biofuel technologies

	Advanced biofuels			Conventional biofuels
	Basic and applied R&D	Demonstration	Early commercial	Commercial
Bioethanol		Cellulosic ethanol		Ethanol from sugar and starch crops
Diesel-type	Biodiesel from microalgae; Sugar-based hydrocarbons	Btl-diesel (from gasification or Fischer-Tropsch synthesis)	Hydrotreated vegetable oil	Biodiesel (by transesterification)
Other fuels and additives	Novel fuels (e.g. furanics)	Biobutanol, DME, Pyrolysis-based fuels		
Biomethane		Bio-synthetic gas	Methanol	Biogas (anaerobic digestion)
Hydrogen	All other novel routes	Gasification with reforming	Biogas reforming	

Source: *Biofuels for Transport, Technology Roadmap,* OECD / International Energy Agency, Paris, France, 2011

is compatible with existing refining and distribution networks and can be processed similar to petroleum[34].

In its 2009 report[35] focusing on the technological development of the biofuel industry Accenture projects the commercial availability of cellulosic bioethanol, butanol and advanced biodiesel in five years. Dedicated energy crops developed with the support of genetic engineering, agricultural, forestry and municipal solid waste is expected to be the dominant feedstock in five to ten years. Bio-crude and complex bio refineries that process biomass feedstock in a wide-range of fuels and by-products should be launched on commercial scale at the same

[34]A more detailed description of these and other additional technologies is available in the *Technology Roadmap*, *Biofuels for Transport*, in M. Stark et al., *Betting on Science: Disruptive Technologies in Transport Fuels* (Accenture, 2009) and in Neil Savage, "The Ideal Biofuel" *Nature* Vol. 474, S9–S11, 23 June 2011.

[35]Ibid.

time. Algae-based biofuels and jet-fuels are predicted to reach commercial scale in the next 15 years.

The Role of Policymakers

Technological progress is essential, but without the right regulatory support biofuels will not be able to fulfill their role in decarbonizing the transport sector. Policymakers should not only focus on supporting the R&D efforts or adopting sound sustainability criteria for biofuels, but at the same time should address the issue of fossil fuel subsidies and put a price on CO_2 emissions. The car, aviation and maritime industry, refineries and distribution networks have to evolve together with bioliquids. The current trade barriers obstructing the trade of biofuels and feedstock should be gradually dismantled. Beyond economic factors policymakers should consider ethical and environmental issues as well. The Nuffield Council of Bioethics offers a complex set of ethical and sustainability principles for policymakers:

1. Biofuels development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements);
2. Biofuels should be environmentally sustainable;
3. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change;
4. Biofuels should develop in accordance with trade principles that are fair and recognise the rights of people to just reward (including labour rights and intellectual property rights);
5. Costs and benefits of biofuels should be distributed in an equitable way;
6. If the first five principles are respected and if biofuels can play a crucial role in mitigating dangerous climate change then, depending on certain key considerations, there is a duty to develop such biofuels.[36]

[36] A. Weale et al., *Ethical framework*, *Biofuels: Ethical Issues* (London, United Kingdom: Nuffield Council on Bioethics, 2011), Ch. 4.

Fields of Cooperation Between the U.S. and the EU on Biofuels

The U.S. and the EU share a common interest in improving their energy security and reducing their dependency on imported oil. Biofuels play a central role in this plan. Together the two players represented 55 percent of global biofuel production and more than 60 percent of consumption in 2010.[37] They have the highest R&D expenditures in the sector and nearly all new demonstration plants are located in these countries. The U.S. and the EU apply the most sophisticated policy tools and have a vital role in regulating international trade in biofuels. The cooperation between policymakers in the European Union and the U.S. is essential to allow for the sustainable future development of the biofuel industry.

Both the U.S. and the EU have to invest significantly more in the *research, development and demonstration* of advanced biofuels. Support schemes should be feedstock and technology neutral. Government supports have to be predictable and be automatically phased out if a technology reaches maturity. The U.S. and the EU should enhance their cooperation on the R&D of advanced agricultural technologies and practices. As developed nations and technology leaders in the biofuel industry, the U.S. and the EU also share a responsibility for *the promotion of technology and best practices* of feedstock and biofuel production in the world.

The U.S. and the EU should coordinate their action on the implementation of sound *sustainability criteria* for biofuels. The EU Renewable Energy Directive requires biofuels to achieve at least 35 percent greenhouse gas savings versus fossil fuels, rising to 50 percent in 2017 and to 60 percent as of 2018 for new plants. But the mounting evidence suggesting that the European Commission calculated with exaggerated emission-reductions and applied a flawed calculation method, which double counts the carbon savings from certain types of biofuels created an uncertain situation.[38] According to a leaked internal document, the European Commission will probably raise the sus-

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[37]Own calculations based on International Energy Agency *World Energy Outlook 2010* and *Technology Roadmap: Biofuels for Transport 2011*.

[38]International Scientists and Economists Statement on Biofuels and Land Use - A letter to the European Commission, October 7, 2011. Available at: http://www.euractiv.com/sites/all/euractiv/files/scientists%20biofuels%20letter.pdf.

tainability criteria to 45-50 percent in 2013 to offset the iLUC effect of biofuels, but will postpone the idea to introduce feedstock-specific GHG reduction targets.[39] The Renewable Fuel Standard in the U.S. requires that at least half of the biofuels production mandated by 2022 should reduce lifecycle emissions by 50 percent, but basically remains silent about the details. The lack of clarity and the uncertainty around sustainability criteria, especially in the EU sends mixed messages to the industry and undermines the credibility of governments' biofuel policies. To avoid such controversies the U.S. and the EU should work together on a *coordinated system of sustainability criteria* that link financial support to GHG performance and incentivize the economical and sustainable use of natural resources.

To facilitate international trade, the transatlantic partners should work together in creating *international certification schemes* for biofuels. These schemes should certify the physical and chemical attributions and the environmental performance of the product, based on life-cycle assessment. Currently there are 67 of such initiatives worldwide, including the European Commission's and the U.S. Environmental Protection Agency's schemes.[40] As the IEA concluded, the "proliferation of standards is increasing the potential for confusion, inefficiencies in the market and abuses such as 'shopping' for standards that meet particular criteria. Such disparities may act as a discouragement for producers to make the necessary investments to meet high standards."[41] The U.S. and the EU should bolster the work of the International Organization for Standardization (ISO), which is currently developing an international sustainability criterion for biofuels.[42] The U.S. and the EU should continue working together on *standardization*.

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[39] "EU to delay action on biofuels' indirect impact," *Reuters*, Sep 8, 2011. Available at: http://www.reuters.com/article/2011/09/08/us-eu-biofuels-idUSTRE7874NP20110908.

[40] Dam J. van (2010), Background document from: Dam et al from "The global efforts on certification of bioenergy towards an integrated approach based on sustainable land use planning," in *Journal of Renewable and Sustainable Energy Reviews* (Utrecht, the Netherlands: Utrecht University, 2010).

[41] *Technology Roadmap, Biofuels for Transport* (Paris, France: OECD / International Energy Agency, 2011).

[42] ISO/TC 248, Project committee: Sustainability criteria for bioenergy. Available at: http://www.iso.org/iso/iso_technical_committee?commid=598379.

The Biodiesel Tripartite Task Force and the Bioethanol Tripartite Task Force created by the United States, the European Union and Brazil to align technical specifications for internationally traded biofuels sets a good example.[43]

Standardization is also important in order to step over the "blending wall" and enable the *proliferation of higher ethanol and biodiesel blends*. The 85 percent ethanol blend called E85 is offered at only 2,200 out of 170,000 fueling stations in the U.S.[44] In the EU ethanol is widely accessible only in Sweden, and available in 15 other member states,[45] as well as in Norway and Switzerland.

It is worth considering the *coordination of targets and mandates* applied to biofuels in the U.S. and the EU. Currently the targets of the transatlantic partners are hard to compare and had been established almost exclusively with regard to the development of their respective internal markets.

The U.S. and the EU should *progressively eliminate trade barriers* impeding the international trade of feedstock and biofuels. The U.S. Senate's June 2011 decision ending a 54 cent per gallon tariff on imported ethanol is a positive step towards this direction, which should be followed by the EU as well. Eventually the EU will be particularly interested in the free trade of biofuels, since its domestic biomass-producing capacity is limited.

The progressive *abolition of fossil fuel subsidies* and the establishment of a *global price on carbon dioxide* and other greenhouse gas emissions are essential for the development of all low-carbon technologies, including biofuels. In its New Energy Finance report[46] Bloomberg

[43]Tripartite task force Brazil, European Union & United States of America: *White Paper on Internationally compatible biofuel standards*, December 2007. Available at: http://ec.europa.eu/energy/renewables/biofuels/doc/standard/2007_white_paper_icbs.pdf.

[44]Stephanie Dreyer, *Approaching the Blend Wall - What it Means for Our Economic Future*, May 11, 2010. Available at: http://www.renewableenergyworld.com/rea/blog/post/2010/05/approaching-the-blend-wall-what-it-means-for-our-economic-future.

[45]Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, the Netherlands, Poland, Spain, United Kingdom.

[46] "Subsidies for Renewables, Biofuels Dwarfed by Supports for Fossil Fuel," *Bloomberg New Energy Finance*, 29 July 2010. Available at: http://bnef.com/PressReleases/view/123.

Table 4. World biomass shipping

Exporter		Product		Importer
Brazil	→	Ethanol	→	EU, U.S., Japan
Malaysia, Indonesia, Argentina, U.S. (through Canada)	→	Vegetable oils and biodiesel	→	EU
Argentina	→	Vegetable oils and biodiesel	→	U.S.
U.S., Eastern Europe and Russia, Argentina, South Africa, Australia	→	Wood pellets	→	EU
Canada	→	Wood pellets	→	U.S.
U.S.	→	Wood pellets	→	Japan

Source: Based on Biofuels for Transport, Technology Roadmap, OECD / International Energy Agency, 2011.

estimated that global fossil fuel subsidies are twelve times higher than the aggregated government spending on renewable support. In this respect, the leader's statement on the G20's Pittsburgh Summit[47] to phase out fossil subsidies in the medium term was an important step, but unfortunately did not set any concrete deadline.

The current revision of biofuel policies on both sides of the Atlantic justifies a stronger international cooperation. There are a number of already established forums for this dialogue. The transatlantic partners have to make better use of the current framework provided by the *Transatlantic Economic Council*, the *Transatlantic Business Dialogue*, the *Transatlantic Legislator's Dialogue* and the *EU-U.S. Energy Council*. The EU-U.S. Energy Council deals with the sustainability of biofuels on workshop-level, since its foundation in 2009. The last ministerial meeting on November 19, 2010 tasked the body's working group with "exploiting the lessons learned from projects for biorefineries using lignocellulosic and algal feedstocks."[48] Research and development efforts are coordinated through the *EU-U.S. Task Force on Biotechnology Research*, which has a working group dedicated to the transatlantic scientific cooperation on bio-based products, including biofuels.

[47] *Leader's Statement*, The Pittsburgh Summit, September 24–25, 2009. Available at: http://www.g20.org/Documents/pittsburgh_summit_leaders_statement_250909.pdf.

[48] *Joint Statement Following the U.S.- EU Energy Council Ministerial*, Lisbon, Media Note, Office of the Spokesman, Washington, DC, November 19. 2010. Available at: http://www.state.gov/r/pa/prs/ps/2010/11/151185.htm.

Potential Geopolitical Implications of the Increasing Use of Biofuels

Energy security and volatile crude oil prices have always been a major concern for policymakers in the United States and the European Union. Gradually decoupling the increasing energy consumption and economic growth from oil imports would have considerable geopolitical, economic and environmental benefits. But efforts made by the United States and the European Union to reduce the transport sector's dependency on oil entails that "oil producing countries can legitimately stake a claim to increased security of demand through a diversification of customers."[49] It is hard to forecast the economic effect of increased biofuel-consumption in the future. The U.S. Department of Agriculture's study assumes that "imports of crude oil would fall by 16-17 percent in 2022. As a result of lower demand and a decline in the import price, the U.S. import bill for crude oil would decline by $61-$68 billion."[50] As a consequence of EU biofuel policies the International Food Policy Institute found that "some countries may experience small negative effects, particularly oil exporters (-0.11% to -0.18% of real income by 2020) and Sub-Saharan Africa (-0.12%) due to the fall in oil prices and rise in food prices, respectively."[51]

Until the proliferation of electric or plug-in hybrid electric vehicles, biofuels provide the only real alternative to reduce the transport sector's dependency on oil. Their high energy density, transportability and compatibility with current distribution infrastructures and vehicles make them an ideal substitute for oil. Another advantage of the biofuel industry lies in the diversity of feedstock, conversion technologies and final products. That flexibility enables biofuel production to be adjusted to local and regional conditions.

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[49]Claude Mandil, Adnan Shihab-Eldin: *Assessment of Biofuels Potential and Limitations* (commissioned by the International Energy Forum).

[50]Mark Gehlhar, Ashley Winston, Agapi Somwaru: *Effects of Increased Biofuels on the U.S. Economy in 2022* (Washington DC, United States: United States Department of Agriculture, Economic Research Service, Economic Research Report Number 102, 2010). Accessible at: http://www.ers.usda.gov/Publications/ERR102/ERR102.pdf.

[51]Perrihan Al-Riffai, Betina Dimaranan, David Laborde, *Global Trade and Environmental Impact Study of the EU Biofuels Mandate* (Brussels, Belgium: International Food Policy Institute / European Commission, 2010).

"Whether or not biofuels play a significant role in the future energy supply mix depends on the development of biofuel production that avoids or lowers food vs. fuel competition while also contributing to environmental goals."[52] Advanced biofuel technologies offer significant improvement in GHG balance and the development of new energy crops will increasingly enable feedstock production to take place on marginal land. But advanced technologies need considerable support from governments, a favorable regulatory environment, and strong cooperation between major economic players to reach industrial scale and to proliferate around the world.

[52]Govinda R. Timislina & Ashish Shreshta, *Biofuels: Markets, Targets and Impacts* (Washington DC, United States: Environment and Energy, Development Research Group, The World Bank, 2010).